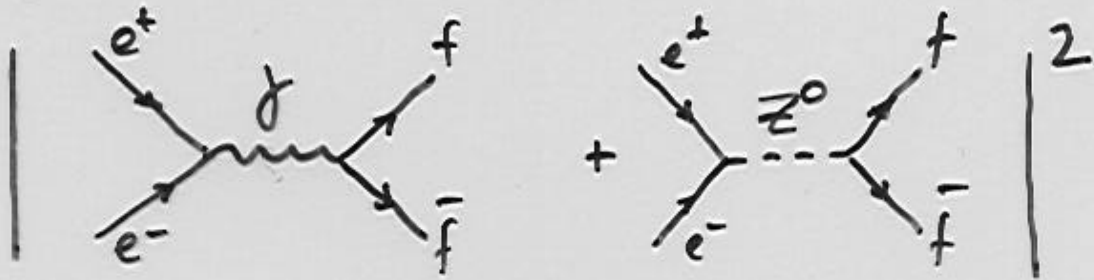


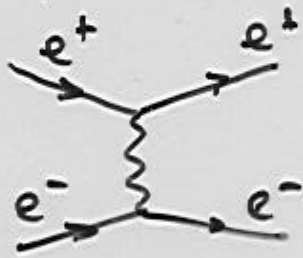
COLISÕES ELECTRÃO-POSITRÃO

FÍSICA em LEP

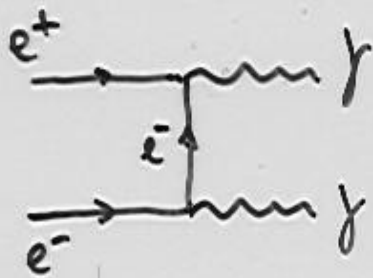
Diagramas de aniquilação:



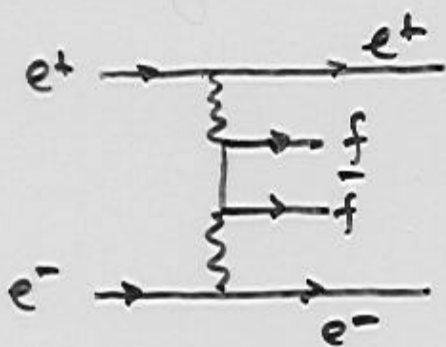
Outros processos:



difusão Bhabha
(interfere com o diagrama de aniquilação)

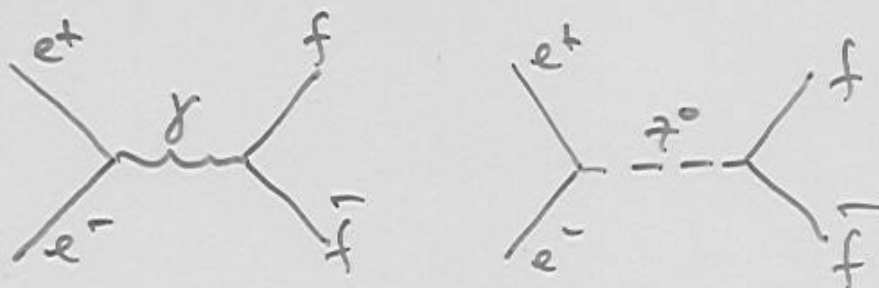


produção de 2 fótons reais



colisão γ - γ (quase-reais)

Amplitudes invariantes



Troca de fótons:

$$M_{\gamma} = -\frac{e^2}{k^2} (\bar{f} \gamma^{\mu} f) (\bar{e} \gamma_{\mu} e)$$

↑ propagador fóton

↑ corrente e.m. fermião f

↑ corrente e.m. do electrão

Troca de Z^0 :

$$M_{Z^0} = -\frac{g^2}{16\cos^2\theta_w} [\bar{f} \gamma^{\mu} (v_f - a_f \gamma^5) f] \left(\frac{g_{\mu\nu} - k_{\mu}k_{\nu}/M_Z^2}{k^2 - M_Z^2} \right) [\bar{e} \gamma^{\nu} (v_e - a_e \gamma^5) e]$$

↑ corrente neutra do fermião f

↑ propagador do bóson Z^0

↑ C.N. do electrão

$$d) \quad a_f = 2I_3^f$$

$$v_f = 2I_3^f - 4Q^f \sin^2\theta_w$$

Parâmetros: e^2 carga eléctrica

θ_w ângulo de mistura

M_Z massa Z^0

$$(g = e/\sin\theta_w)$$

OBSERVÁVEIS

1. Seção Eficaz:

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)^{\gamma} + \left(\frac{d\sigma}{d\Omega}\right)^{Z} + \left(\frac{d\sigma}{d\Omega}\right)^{\gamma Z}$$

$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2}{4s} N_c \left[\mathbf{a} (1 + \cos^2 \theta) + 2 \mathbf{b} \cos \theta \right]$$

$$\mathbf{a} = \underbrace{Q_e^2 Q_f^2}_{\gamma} + \underbrace{2 Q_e Q_f v_e v_f}_{\gamma Z} R(\chi) + \underbrace{(v_e^2 + a_e^2)(v_f^2 + a_f^2)}_{Z^0} |\chi|^2$$

$$\mathbf{b} = \underbrace{2 Q_e Q_f a_e a_f}_{\gamma Z} R(\chi) + \underbrace{4 v_e v_f a_e a_f}_{Z} |\chi|^2$$

$$\chi = \frac{1}{16 \sin^2 \theta_w \cos^2 \theta_w} \frac{s}{(s - M_Z^2 + i M_Z \Gamma_Z)}$$

v_f	a_f		
+1	+1		neutrinos
$-1 + 4 \sin^2 \theta_w$	-1	e, μ , τ	leptões
$-1 + \frac{4}{3} \sin^2 \theta_w$	-1	d, s, b	quarks
$+1 - \frac{8}{3} \sin^2 \theta_w$	+1	u, c, t	quarks

SEÇÃO EFICAZ TOTAL $e^+e^- \rightarrow f\bar{f}$:

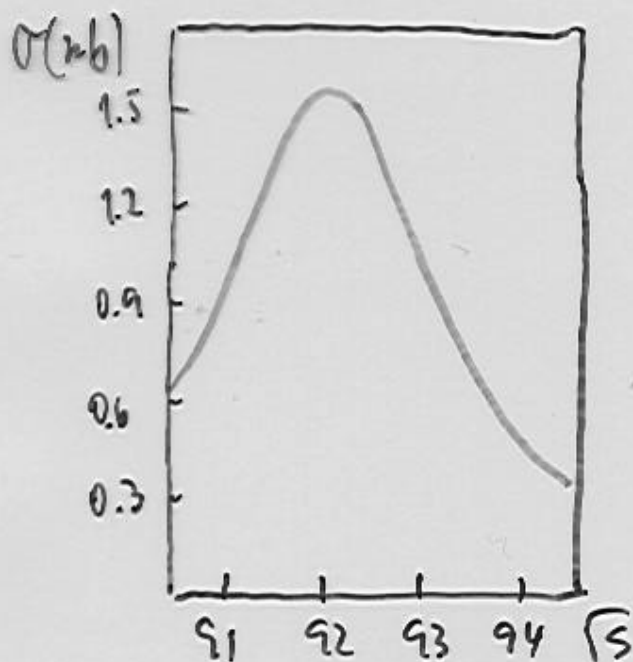
Dependência em s

QED: troca de γ

$$\sigma_f(s) = \sigma^0 \frac{\Gamma_z^2/4}{(\sqrt{s} - M_z)^2 + \Gamma_z^2/4} + \frac{4\pi\alpha}{3s} Q_f^2$$

↑ Breit-Wigner
ressonância Z_0

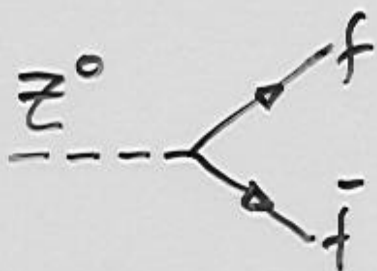
$$\sigma^0 = \sigma(s=M_z^2) = \frac{12\pi}{M_z^2} \frac{\Gamma_{ee} \Gamma_{ff}}{\Gamma_z^2}$$



Γ_{ff} : largura parcial

$\Gamma_z = \sum_f \Gamma_{ff}$: largura total

2. LARGURA do Z^0



factor de vértice:

$$-i \frac{g}{\cos \theta_w} \gamma_\mu \frac{1}{2} (v_f - a_f \gamma^5)$$

$$\Rightarrow \Gamma(Z \rightarrow f\bar{f}) = \frac{g^2}{48\pi \cos^2 \theta_w} (v_f^2 + a_f^2) M_Z$$

$$\frac{g^2}{\cos^2 \theta_w} = \frac{8M_Z^2 G}{\sqrt{2}} \Rightarrow$$

$$\Gamma_f = \frac{G M_Z^3}{6\sqrt{2}\pi} (v_f^2 + a_f^2)$$

3. ASSIMETRIA FRENTE - TRÁS

Definição:

$$\frac{d\sigma^f}{d\Omega} = \sigma_0 \left[(1 + \cos^2 \theta) + \frac{\theta}{3} A_{FB}^f \cos \theta \right]$$

$$A_{FB}^f = \frac{N_f(\cos \theta > 0) - N_f(\cos \theta < 0)}{N_f \text{ total}}$$

Modelo standard:

• no pico $s = M_Z^2$:

$$A_{FB}^f = \frac{3}{4} A^e A^f$$

$$c/ A^e = \frac{2v_e a_e}{v_e^2 + a_e^2}$$

$$A^f = \frac{2v_f a_f}{v_f^2 + a_f^2}$$

• em função de s :

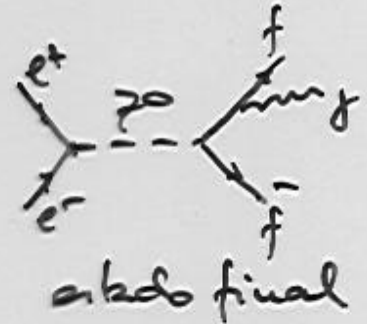
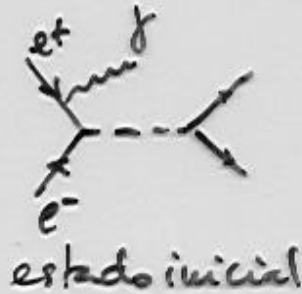
$$A_{FB}^f(s) = \frac{2R(\chi) Q_e Q_f a_e a_f + |\chi|^2 4v_e a_e v_f a_f}{Q_e^2 Q_f^2 + 2R(\chi) Q_e Q_f v_e v_f + |\chi|^2 (v_e^2 + a_e^2)(v_f^2 + a_f^2)}$$

$$\chi \equiv \chi(s)$$

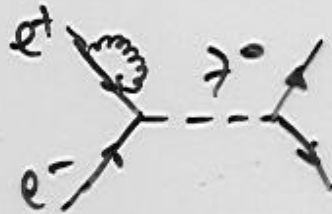
CORRECCÖES RADIATIVAS

Radiação QED :

Fotões reais

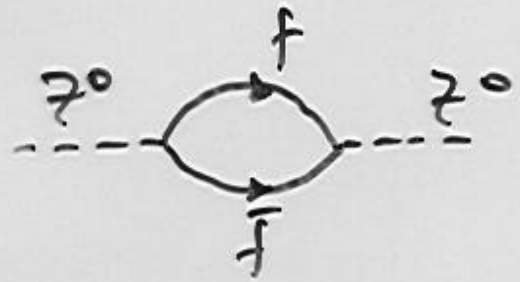


Fotões virtuais

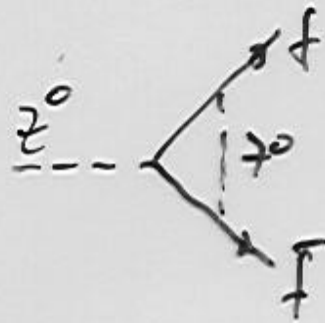


Correções electrofracas:

correções ao propagador



correções de vértice

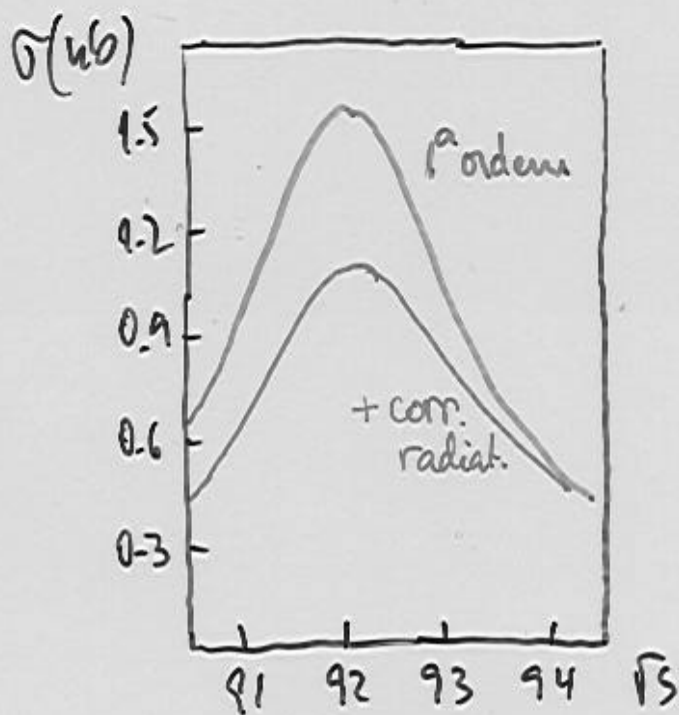


Seção eficaz e correções radiativas:

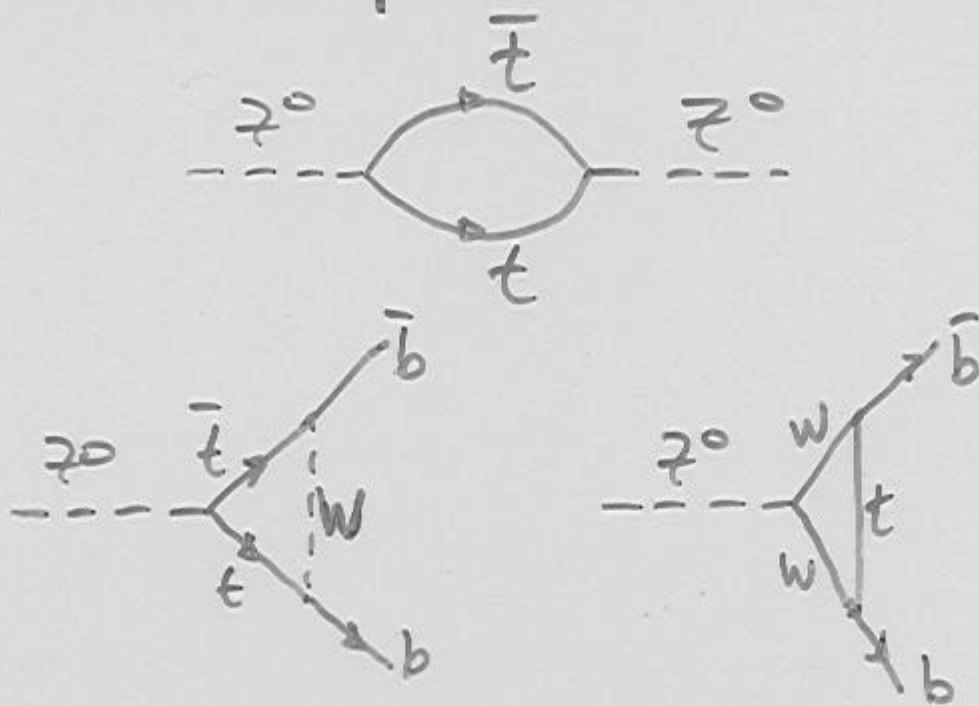
Alteração da forma da ressonância:

$$\sigma_0 \rightarrow \sigma_0 \left(\frac{\Gamma_z}{M_z} \right)^\beta \quad \beta = \frac{2\alpha}{\pi} \left(\ln \frac{M_z^2}{m_e^2} - 1 \right)$$

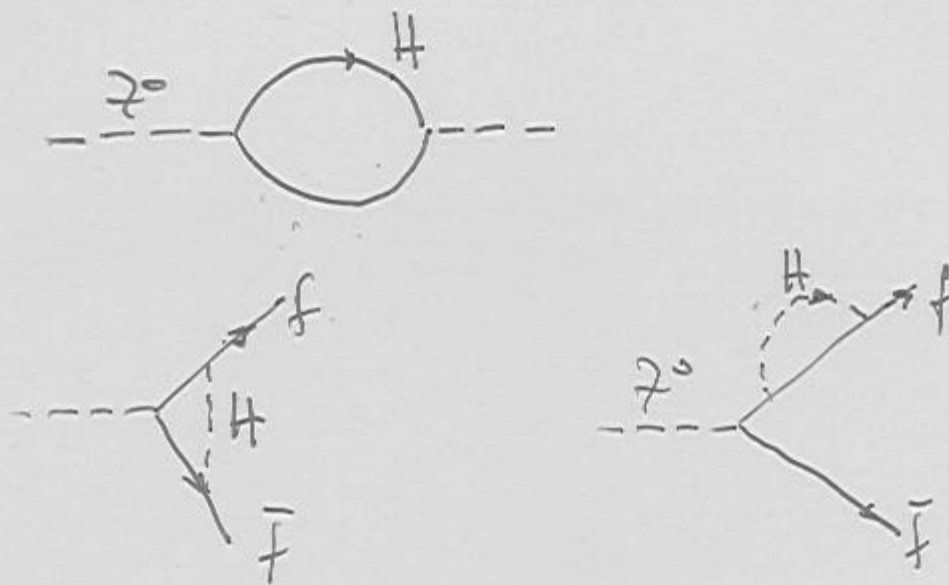
$$\frac{1}{s - M_z^2 + i M_z \Gamma_z} \rightarrow \frac{1}{s - M_z^2 + i s \frac{\Gamma_z}{M_z}}$$



Correções dependentes de M_{top} :



Correções dependentes de M_{Higgs} :



Medidas de precisão

Utiliza-se como input três parâmetros bem conhecidos:

$$\alpha = \frac{1}{137.03604}$$

constante estrutura fina

$$G_\mu = 1.16344 \cdot 10^{-5}$$

, a partir do tempo de vida do μ

$$M_Z = 91.17 \pm 0.03$$

, LEP

O ângulo de mistura Θ_w é:

$$\sin^2 \Theta_w \cos^2 \Theta_w = \frac{\pi \alpha}{\sqrt{2} G_\mu M_Z^2} \quad (1^\circ \text{ ordem})$$

$$\sin^2 \Theta_w \cos^2 \Theta_w = \frac{\pi \alpha}{\sqrt{2} G_\mu M_Z^2 (1 - \Delta\Gamma)}$$

$$\Delta\Gamma \equiv \Delta\Gamma(M_{\text{Higgs}}, m_{\text{top}}, M_Z, \alpha, G_\mu, m_q)$$

Medida de Θ_w :

$$\Gamma_{ff} \sim (v_f^2 + a_f^2)$$

$$A_{FB}^f \sim \frac{v_e a_e v_f a_f}{(v_e^2 + a_e^2)(v_f^2 + a_f^2)}$$

$$\begin{aligned} a_f &= 2 I_3^f \\ \Gamma_f &= 2 I_3^f - 4 Q_f^2 \sin^2 \Theta_w \end{aligned}$$

↑